REMARKS

This amendment is in response to the office action of March 28, 2007 in which the Examiner rejected the claims over Streetman alone or in combination with a variety of secondary references.

The Examiner's rejection of the claims is respectfully traversed for the reasons set forth below.

At the outset, applicant wishes to note that laser radiation and black body radiation are profoundly different. Laser energy is coherent, that is it consists of light or electromagnetic (EM) energy having a single wavelength centered almost exclusively around a peak wavelenght. An example of laser radiation is the light produced when laser material is pumped with energy of a particular wavelength, which energy is converted to a coherent beam of EM energy of a similar or different wavelength. Black body radiation is a form of EM having a spectrum or distribution of frequencies. An example of black body radiation is that produced when an object is heated in a flame. The body radiates over a range of wavelengths broadly centered around a peak. In other words, a laser is a single frequency, and black body radiation is a broad mixture of frequencies. Also, black body radiation and laser radiation can be focused or concentrated; or it can be diffuse or scattered.

This difference is important. Light or EM energy produces the so called photoelectric effect in certain types of materials. The incoming light of a certain wavelength, corresponding to the response of the material, is absorbed by the material creating electron-hole pairs or electricity. However, the incoming light must have a particular threshold or quantum of energy. Light below the threshold is absorbed but does not produce electron-hole pairs, it produces heat, which is considered wasted energy. Light above the threshold is absorbed and likewise produces heat. Only light at or very close to the threshold is absorbed to produce electron-hole pairs. Thus, of all the black body radiation directed at the material, only a small portion of the energy absorbed is

converted to electricity. This is sometimes referred to as quantum efficiency.

Laser energy is different because it is energy of more or less a single frequency or energy level. If it is below or above the threshold it will likewise be absorbed and converted to heat. However, if it is at the threshold, it will be converted to electron-hole pairs. The difference is that, because the laser is coherent, i.e. one frequency, if it corresponds to the threshold wavelength, all or nearly all of it will be absorbed and converted to electron-hole pairs. Therefore, the quantum efficiency is relatively much higher than black body radiation.

The above discussion is somewhat oversimplified, but the general proposition is accurate, namely that one can convert more energy into electricity if one tunes the incoming light to the sensitivity of the material. Conversely, if one can engineer the sensitivity of the material, one can tune the material to the available wavelength of the incoming light.

The present invention employs laser light to transmit power. The laser is tuned to a certain frequency. Wavelength and frequency are inversely related and are sometimes interchanged to define the energy of the light by the relation $E = h \bullet \dot{\eta}$, where E is energy, h is Plank's constant, and $\dot{\eta}$ is frequency. The frequency $\dot{\eta}$ and wavelength λ are related as $\dot{\eta} = 1/\lambda$. Thus the energy content of the laser is defined by the wavelenght (or frequency). With this in mind, applicant now refers to the art cited by the Examiner.

Streetman is a thermophotovolaic (TPV) device for converting black body radiation produced from combustion of natural gas into light, (a process known as incandescence) and converting the light into electricity by use of photovoltaic (PV) cells. The quantum efficiency is low because only a small portion of the light centered near the response characteristic of the PV cells is converted to electron-hole pairs.

Streetman, also discloses an embodiment supplementing heat

produced by the combustion of natural gas with solar energy to produce electricity. In this embodiment, the PV cells are responsive to the light radiation produced by the gas and the light of the sun. However, only a narrow portion of these light sources convert to electricity. Most of the energy is wasted.

Streetman, in essence, is a way of converting black body radiation in the form of heat and light to energy. Streetman does not contemplate or use or suggest the use of a laser to produce the light, nor does Streetman suggest that the incandescent light from the burning of natural gas is directed into the device from the exterior. Indeed, Streetman simply produces heat by combusting natural gas in a mantle within a spherical chamber. In another embodiment using solar radiation, Streetman allows sunlight to impinge directly on the photovoltaic cells. The cells happen to be disposed in an open hemispherical chamber. However, such arrangement is no different than a conventional solar collector, with the exception that Streetman supplements the solar energy with the fuel produced incandescent light. Thus, in a first embodiment of Streetmen, heat is converted to light which in turn is converted to electricity by PV conversion, and in the second embodiment, solar radiation supplements the incandescent radiation.

In the first embodiment of Streetman there is no small aperture in the housing to receive the light, as the housing is closed to light and only has an opening for receiving the gas. In the second embodiment, the light comes from the sun into a hemispherical collector lined with PV cells. The light from the incandescent source is also received by the PV cells to produce electricity, but in the latter case the light is not integrated within the sphere. Indeed, any light or heat reflected from the cells is lost by escape through the open top of the hemisphere.

In the broadest sense, the open hemisphere in Streetman is an "aperture". However, the aperture, or open top, is not substantially

smaller than the surface area of the hemisphere. The area of a circle (the open top or aperture of Streetman) is $\pi \bullet R^2$ the area of the hemisphere is $1/2 \bullet 4\pi R^2$. For any value of R, the area of the aperture is about one half the area of the hemisphere. In the invention, the area of the aperture is about 1% the area of the interior of the sphere. Thus, by comparison, the aperture in Streetman is not substantially different than the area inside the hemisphere.

Another important difference with Streetman, is that the reference does not mention or suggest the possibility of using diffraction limited laser radiation as the light source for PV conversion to electrical power. As should be apparent, the collection of solar radiation or thermally produced radiation to produce electrical power is well known. Indeed, this is the conventional process for converting available light into a useful form of electricity. While one can readily imagine the use of a low power laser to carry a communications signal which is converted to an electrical communications signal by a PV device, the collection of Laser radiation to produce electrical power is not a conventional process.

Streetman, as noted above in describing his gas combustion based TPV design, fails to explain why he uses a spherical cavity and not for example a cylinder or a square box. He also does not suggest that it is possible or desirable to perform the photon recycling process of the invention that significantly increases the conversion efficiency of the cavity. In other words, the configuration of Steetman is not terribly important to the process. A sphere is convenient, but any shape would do. In the invention, the spherical shape greatly enhances efficiency.

The present invention uses a monochromatic laser beam for an energy source produced externally of the sphere. The invention is not a TPV design of the prior art, but a photovoltaic (PV) design which converts the laser beam directly into electricity. This laser beam wirelessly carries power produced at one location to another remote

location. The invention is thus primarily concerned with power transmission in space where wires are not a practical expedient.

In addition, the laser beam is a narrow coherent beam. This means that a lot of power can be carried in beam with a minimal spot size. Further, the beam does not spread as it moves through space. Indeed, the beam remains very tight over long distances. Black body radiation of the type described in Streetman, moves in all directions. Unless focused by a separate lens or mirror, such light will dissipate inversely as the square of the distance from the source. Thus as a practical matter, it is not possible to transmit black body radiation over long distances without some way to focus the radiation. A laser, on the other hand, by definition, produces a coherent beam which does not dissipate with distance.

There have been schemes which contemplate the use of a laser to transmit power in space. However, such schemes do not use an integrating sphere to increase efficiency. The integrating sphere recycles and captures most of the incoming laser light for conversion to electron-hole pairs by the PV cells. In the conventional system, the light reflected from the cell is lost. In the invention, the light reflected from the cell bounces around until it is absorbed for conversion. Of course some light may be lost as heat, but this amount is small in comparison to the total energy transmitted.

In Streetman, a primary energy source is used to heat an emitter to high temperatures, i.e. the combustion temperature necessary to create incandescence (800 to 2200 deg. C), and the resulting incandescence or diffuse radiation is converted into electricity by proper photovoltaic cells. PV design of the invention converts a coherent laser beam directly to electricity at about 60 deg. C. Thus, the invention begins with a much lower temperature and reduces the potential thermal losses from the outset.

Streetman does not mention the unique properties of a near diffraction limited, coherent laser beam as compared to solar or any other artificially generated radiant energy. Indeed, Streetman is trying to use conventional sources, i.e. fossil fuel, or solar radiation to produce electricity. However, the invention is adapted to employ a laser to transmit energy from a source (laser) to a receiver (integrating sphere). This is particularly important in terms of Laser Power Beaming or Wireless Power Transmission, to which the invention pertains, where long distances between the laser source and the spherical cavity receiver are common. A high quality laser beam in space suffers very limited beam broadening. This allows the use of a very small entrance aperture for the cavity independent of the magnitude of the beam power. The small aperture results in more efficient photon recycling and higher conversion efficiency.

The potential of Laser Power Beaming for space and deep space explorations has been investigated by NASA since the mid-seventies. Several experts have complained about the lack of Photovoltaic cells that would optimally match the frequency requirements of the existing high power lasers like Nd:YAG or Chemical Lasers. For example for Nd:YAG lasers, having a frequency of 1064 micron, a photovoltaic cell with an energy bandgap of slightly less than 1.17 eV is needed. However, as of today such a cell does not exist.

Wanlass, is today considered the foremost expert in the field of band-gap engineering. His expertise stems solely from his involvement in the TPV and multi-junction cell areas. The cited referece does not consider or suggest the extension of TVP cells to laser applications. Thus, the Examiner's suggestion is believed to be based on conjecture and is unsupported by the cited art.

It is believed that claim 1 is patentable over the art, and that the claims depending therefrom are therefore patentable. It is believed that

the remaining references do not either alone or in combination disclose or suggest the claimed subject matter.

Claims 13 and 30 have been amended in order to more correctly describe the subject matter recited therein. In the invention, the laser light may be multiplexed so that the beam carries power and communications components which have been mixed or multiplexed. The light is directed into the sphere where the communications component and power component are demultiplexed or separated by means of the filters and PV cells which are selectively responsive to the several components. Thus a power component multiplexed or mixed with a communications component is carried to the sphere and the power and communications components are separated or demultiplexed by the filters to perform different functions. The claim as originally presented incorrectly recites this concept which is clearly disclosed in the specificatio.

In view of the foregoing, it is respectfully requested that the Examiner reconsider his rejection of the claims, the allowance of which is earnestly solicited.

If additional fees are required, the Commissioner is authorized to charge Deposit Account 504147 for such fees or credit any overpayment thereto.

Respectfully submitted,

John De Luca
Attorney for Applicant
Reg. No. 25505

CUSTOMER NO: 66804